PAV-91-03

Trial Sections with Polymer-Modified Asphalts on Highway 400

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Abstract:

In July, 1990, the Ministry of Transportation of Ontario (MTO) built trial sections on Highway 400, near Innisfil, to compare standard and modified HL 1 mixes in terms of their effectiveness to resist rutting and low temperature cracking. In addition to Premium Asphalt from Petro-Canada, the additives used for the trial sections include Novophalt, Neoprene, Vestoplast, and tire rubber (#80 mesh) which had not been evaluated previously by the MTO. The selected test site represents a typical highway section in a colder environment experiencing heavy traffic induced rutting. The mix design for the trial sections was modified to yield results in 2-5 years.

Novophalt was produced by blending reprocessed granular low density polyethylene with asphalt cement in a high shear mill using a special type of mobile blending unit set up at the plant site. The same equipment was used to mix tire rubber, Ultrafine GF-80, with asphalt cement. Neoprene and Premium Asphalt were delivered in a separate dedicated tanker to the plant site for mixing with aggregates. Vestoplast, produced from alpha olefins as granular solid particles, was added to the heated virgin aggregates in the drum mix plant through the centre-feed system. During this process, the aggregate was precoated with Vestoplast before being mixed with asphalt cement.

Initial experience suggests that construction of asphalt pavement with Vestoplast, Novophalt, Neoprene, tire rubber and Premium Asphalt using conventional equipment is feasible. However, special blending equipment is required for mixing Polyethylene (Novophalt) and tire rubber with asphalt cement.

The main purpose of this report is to summarize the experience gained in the construction of the trial sections and the handling of the additives used in each section, and to present the proposed laboratory testings and field evaluation techniques for assessing the performance of individual test sections.

Comments: Contract 90-07

Key Words: asphalt, mix design, additives

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1/ Introduction

The Research and Development Branch initiated Project 21216 in late 1989 to investigate the relative field performance of polymer-modified and premium asphalts which had not been evaluated previously by the Ministry of Transportation, Ontario (MTO). The project involves testing of the modified asphalts in a control field experiment, primarily for their potential to improve rutting resistance in comparison to the standard HL 1 mix without adversely affecting the low temperature performance of the pavement containing the modifier. The modified asphalts selected for this study are Premium Asphalts from Petro-Canada and polymers, including Polyethylene, Neoprene, Vestoplast, and tire rubber. The field experiment program envisaged the necessity of constructing trial sections on a heavily trafficked section of highway located in a colder climate and experiencing the problem of rutting. Having reviewed several potential test sites in the Southwestern Region, the site on Highway 400 near Barrie was selected to construct 7 test sections as part of the MTO's major rehabilitation contract 90-07.

This report describes the experimental design, construction procedures, quality control, and proposed laboratory and field evaluation methodologies for assessing the performance of the trial sections. The field performance evaluation will focus on rutting, roughness, cracking, surface defects, and the overall structural strength of the pavement sections. The laboratory testings will investigate the potential of the materials to resist rutting and low temperature cracking.

2/ Need for Trial Sections

In recent years, highway pavements in Ontario have been experiencing severe rutting problems. The rutting pattern has changed from a smooth depression to double ruts in heavy truck traffic locations [1]. In 1987, the MTO conducted a study to investigate the problem of rutting, and concluded that rutting is caused by a) an increase in heavy traffic, and b) a change to the use of higher pressure (110 psi) radial tires, from bias ply tires (85 psi). Apparently, the use of radial tires provides increased benefits in terms of fuel economy, improved maintenance costs, and increased load capacity [2]. Thus, the study recommended the use of rut resistant mix to meet the demand placed on asphalt pavements by the increased traffic loads.

Following this recommendation, the MTO has accepted in principle the use of premium quality 100 percent aggregates in asphalt mixes to mitigate rutting. However, their use is often hampered by the environmental impact of hauling large quantities of material over already congested highways coupled with the additional cost [3]. As an alternative, the Ministry has also been investigating the use of various additives for improving pavement performance [3, 4, 5, 6]. Further, many agencies have been active in studying the effects of different additives on rutting of asphalt pavements [7, 8]. Until now, the studies carried out by the MTO have been inconclusive because both the control and treated sections have shown no evidence of rutting.

Consequently, the MTO initiated a new field experiment to evaluate within a reasonable period of time, the relative performance of polymer modified and premium asphalts which have not been tested previously by the MTO.

3/ Scope and Objectives

The main objective of this field experiment study is to verify the manufacturers' claims regarding the use of their respective additives to resist rutting without adversely affecting the low temperature characteristics of the mixes. It is necessary to obtain results of the performance of individual test sections within a reasonable period of time. Thus, the trial sections were slightly under-designed to enhance speedy assessment of their relative performance.

More specifically, the study will focus on the following areas of interest:

1) rutting resistance of the polymer-modified mixes,

2) materials' susceptibility to low temperature cracking,

3) structural strength and the overall performance of polymer-modified asphalt pavements,

4) material handling and construction procedure.

4/ Asphalt Additives and Suppliers

As discussed in Section 1, the materials selected for this project include plastics (Polyethylene, Neoprene, and Vestoplast - a form of polyolefin), rubber from discarded tires and Premium Asphalt from Petro-Canada. These additives are added to the mix to increase stiffness at higher temperatures (which will improve resistance to deformation) and to maintain the required low stiffness at low temperatures (to minimize cracking). The following sections describe briefly the different types of additives used and their respective suppliers who were responsible for blending the additives with either the asphalt cement or the aggregate.

Additive "A" (Polyethylene)	Novophalt America Corp. 107 Carpenter Drive Sterling, VA 22170 Walter J. Tappeiner, President (703) 435-6600 ETP Technologists Inc. (supplier) St. Laurent, Quebec
Additive "B" (Neoprene)	DuPont Canada Inc. Box 2200, Streetsville Mississauga, Ont L5M 2H3 Allan G. Smiley, Plastics (416) 821-5989
Additive "C" (Vestoplast)	Huels America (manufacturer) James A. Scherocman (513) 489-3338 W. Schutz KG (supplier) 6290 Weilburg 2, West Germany

Additive "D" (Premium Asphalt)	Petro-Canada Research Department 2489 North Sheridan Way Sheridan Park, Ontario L5K 1A8 Laverne Miller (416) 896-6742
Additive "E" (Tire Rubber)	Rouse Rubber Industries, Inc P.O. Box 831, Vicksburg, U.S.A. Michael Rouse (601) 636-7141

The asphalt cement used for blending with various polymer additives was an 85-100 PEN paving asphalt from Petro-Canada's Clarkson Refinery (Table 1).

5/ Experimental Design of Trial Sections

5.1/ Location of Test Site

The test site was located on the southbound driving lane of Highway 400, about 0.6 km north of Highway 89, in the Township of Innisfil (Figure 1). This site was selected because it meets the following criteria:

1) it represents a typical highway section with heavy traffic induced rutting,

2) it has a uniform subgrade and subbase strength as indicated by the falling weight deflectometer,

3) it is subject to a cold environment and has easy accessibility for performance evaluation.

5.2/ Description of Existing Pavement Condition

In 1987, the Geotechnical Section, Southwestern Region, observed the occurrence of moderate to severe wheel track rutting on Highway 400 between the Highway 89 interchange and Highway 93 at Crownhill and requested a detailed investigation using the Laser Road Surface Tester [9]. The investigation revealed that major rehabilitation work was required on discrete pavement sections on the north and southbound driving lanes between Highway 89 and Highway 93 because these sections had reached the action level (i.e. at least 50% of each 100 m length had rutting greater than 19 mm). The proposed rehabilitation work involved milling of the existing pavement to a depth of 90 mm and reuse of the materials removed from the top 30 mm thick pavement. The reclaimed asphalt paving (RAP) material was stockpiled separately before mixing with virgin aggregates. The two way average annual daily traffic (AADT) for this section of highway was 36,000 (6,000 vehicles per lane) in 1988.

5.3/ Description of Trial Sections

The experiment program forms part of the rehabilitation work on various sections of Highway 400 totalling about 28 km. It consists of one control and six treated sections (Figure 2). The trial sections did not include the RAP materials in the mix design but used 50 mm thick specially designed HL 4 mix for the binder course and 40 mm thick standard HL 1 mix for the surface course. The special

design for the binder mix excluded screenings and used a higher asphalt content (5.9%) and a higher content of fine aggregates (56%) in order to obtain results in 2-5 years (see Section 5.4).

Deflection measurements using the falling weight deflectometer (FWD) were carried out before and after the construction at 30 m intervals, throughout the entire 2.82 km length, to assess the uniformity of the test site. The test results, as shown in Figures 3 to 6, indicate that the mean deflection for each test section varies from 0.06 mm to 0.0743 mm and is considered acceptable.

5.4/ Mix Design

The objective of the mix design for the trial sections is two fold. First, to produce proven modified HL 1 mixes which can be used to evaluate the effectiveness of additives in improving rutting resistance of the mixes. Second, to select job mix formula and mix design for HL 4 mixes in such a way as to yield results in 2 to 5 years. This was achieved by blending 44% HL 4 stone (course aggregate, C.A.) with 56% asphalt sand (fine aggregate, F.A.#1) without screenings to produce a total 55% passing the 4.75 sieve (Table 2). A proven HL 1 mix was produced according to the standard mix design procedures and specifications with respect to aggregate gradation and Marshall properties. Thus, a blend of 50% HL 1 stone (C.A.), 37.5% asphalt sand (F.A.#1) and 12.5% screenings (F.A.#2) was used for HL 1 mix to obtain a total 47.7% passing the 4.75 sieve as shown in Table 2. The HL 1 mix for the main contract was modified by blending 43.5% C.A. (100% crushed traprock) with 32.5% fine sand, and 24% RAP to provide a high rut resistant mix. Thus, the discrete pavement sections in the main contract are expected to last much longer than the trial sections.

Mix design data for HL 1 and HL 4 mixes for the test sections are given in Tables 3 and 4. For each mix type, a total of five mixes having the same aggregate gradation but variable asphalt content were chosen. Based on Marshall properties, mix #3 in Table 3 was selected to produce a proven HL 1 modified mix. However, as previously discussed, a low stability mix (mix #6 in Table 4) was selected for HL 4 binder course to obtain results within a reasonable period of time.

All test sections used the same type of aggregates as those used in the control section - both in the binder and the surface course. The only difference among the test sections was the additive, the proprietary product supplied by the participating agents. Obviously, it is difficult to predict the exact time of failure as this will be dependent on many factors such as peak and duration of summer temperatures, tire pressures, and frequency and the type of traffic loadings. However, experience suggests that the modified mix design for the trial sections will likely yield results in 2 to 5 years.

6/ Construction of Trial Sections

Construction of the test sections commenced on July 24, 1990 and it was carried out by Allan G. Cook Construction Company, Ltd., Barrie, Ontario. The ambient temperatures during paving operations ranged from 23-28°C. The asphalt concrete mix plant was a portable CMI drum mixer with 300 tph capacity, located on Highway 90 West, in Barrie. The pavement trial sections were constructed successfully using conventional equipment (Figure 2). For the most part, the contractor was able to carry out normal paving operations in the same manner as for the conventional mixes. In trial section 5, standard 85/100 grade asphalt cement was used for the binder course and the Premium Asphalt for the surface course. This was because the supplier inadvertently supplied 85/100 asphalt cement in place of the Premium Asphalt at the time of laying the binder course for trial section 5. This resulted in the construction of an additional trial section 7 with the Premium Asphalt in both binder and surface course layers. Further, the length of each section is not 500 m as intended but varies from 325 m to 545 m (Figure 2), depending on the amount of additive mix that was made available at the site during construction.

6.1/ Vestoplast

Vestoplast is produced from α olefins and supplied in bags by Huels America as granular solid particles. It has a specific gravity of less than 1 and a faint odour. This polymer was added to the heated virgin aggregates in the mix plant to form a thin coating around the aggregates before they were mixed with asphalt cement. This coating is expected to promote the binder adhesion to the aggregate in addition to increasing the rutting resistance of the overall mix. The RAP centre-feed system (Figures 7 and 8) was used to feed the Vestoplast into the mix plant containing the virgin aggregate. This system consisted of a vertical hopper and a conveyor belt moving at 8.26 feet per minute. The gate opening at the bottom of the hopper was adjusted to 228 mm x 87 mm to feed the required amount of Vestoplast needed to produce the mix at the rate of 4 tpm. The amount of Vestoplast added to the mix was 7% by weight of asphalt cement which translates into 14.5 kg per minute. During this process the aggregate was precoated with the melted Vestoplast before being mixed with asphalt cement.

6.2/ Novophalt

Novophalt modified asphalt cement, produced by Novophalt America Corp., contains 5% by weight of reprocessed granular low density polyethylene (LDPE) and 85 to 100 penetration grade asphalt cement. The reprocessed LDPE, obtained from ETP Technologies Inc., Canada, was blended with asphalt cement in a high shear mill using a special type of mobile blending unit (Figures 9 and 10) set up at the hot mix asphalt (HMA) plant site. This blending unit has three tanks — two for mixing and one for product storage. All three tanks were heated and equipped with mechanical agitation to ensure uniform polymer dispersion during production and storage of Novophalt. The high shear milling process was used during blending to achieve homogeneous dispersion and uniform size of the LDPE molecules. The equipment was then hooked up to the supply lines of the HMA plant when it was ready for production so that the modified asphalt cement could be supplied for mixing with aggregates to produce the new paving mixture. A slightly elevated mixing temperature (165°C) was required due to the higher viscosity of the Novophalt.

6.3/ Neoprene

Neoprene was supplied by DuPont Canada Inc., and blended with asphalt cement by Norjohn Limited, Emulsion Division, in Ontario. The modified asphalt was produced by adding 2.7% by weight of Neoprene to the 50-50 blend of 85/100 PEN and 150/200 PEN grade asphalt cement at a temperature of 165°C. The modified asphalt cement was then delivered in a separate, dedicated tanker to the hot mix plant. This tanker was stationed at site alongside the storage tank of the original asphalt. The hot oil jacketed metering pump system of the asphalt plant and 76 mm diameter flexible hose were used to deliver the polymerized asphalt cement directly from the tanker to the mixing drum.

6.4/ Premium Asphalt Cement

Premium Asphalt cement is a newly formulated asphalt product developed at Petro-Canada's Sheridan Park Research and Development Center in Mississauga. It is used for the construction of superior pavements to serve high traffic and heavy loading applications. It is produced from oils without the use of polymer additives and contains no waste materials. Premium Asphalt was supplied by Petro-Canada in a separate tanker which was hooked-up directly to the drum mix plant in the same manner described in Section 6.3.

6.5/ Tire Rubber

Rouse Rubber Industries supplied the tire rubber, UltraFine powder (#80 mesh) which was mixed with the 85/100 grade asphalt cement at the site using the Novophalt equipment (Figure 9). At the beginning, the modified asphalt cement plugged the strainer (screen) in the AC feed loop during the addition of the polymerized rubber asphalt. This problem was overcome by removing the screen and cleaning it before it was reinstalled. Also, the amount of rubber added to the asphalt was reduced from the original amount of 10% to 7%, to ensure smooth operation.

In general, the hot mix production in the drum mixer continued smoothly at the mix temperature of 140 –150°C. The temperature of the mix was monitored by a thermocouple installed at the outlet of the drum mixer just before the conveyor belt which carried the hot mix to the holding bin.

6.6/ Quality Control and Sampling

Representative test samples of aggregates, asphalt cement, modified asphalts and their hot mixes were taken at the time of mix production for each test section during construction. The binder samples were taken directly from each tanker and the hot mix samples were obtained from the conveyor at the exit of the drum mixer (Figure 11). For each mix type, two bags of hot mix (approximately 30 kg each) and 1 gallon of asphalt cement were taken. In situ quality control and sampling was carried out by the Ministry's own mobile laboratory by taking plate samples (one per test section) while laying the mix (Figure 12) and by coring (two per test section) after compaction at randomly selected locations. The test results from these field samples are summarized in Appendix 1.

6.7/ Laying Procedure

The hot asphalt concrete mix produced at the CMI drum mix plant was transported by trucks of varying capacity (24-32 t). At the job site, the mix was transferred into a Barber-Green BG245 asphalt paver which spread the material to a predetermined thickness over the milled and tack coated pavement section while moving at a speed of 7-8 m per minute. The laid mix was then compacted using a Dynapac CC42, 10 t vibratory roller followed by a Dynapac CP21, 18 t rubber tired roller. The temperature of all the mixes in the paver just before laying was 130°C except for the mix with polyethylene additive, which recorded a temperature of 140°C. First, the 50 mm binder course was laid for all the test sections starting with the control section. Initially, there was some problem during compaction, because the mix started shoving slightly under the Dynapac vibratory steel roller and it

could not pass 3 times as specified. However, this problem was overcome by allowing the mix to cool to 120°C. As well, there was some problem of pick-up (Figure 14) while compacting the Neoprene modified asphalt mix with the rubber tired roller. This problem was resolved by allowing the mat to cool somewhat before smoothing the surface and also by cleaning the rubber tired roller of any adhesive materials.

7/ Proposed Field Performance and Laboratory Evaluation

The proposed field performance evaluation will comprise the measurement of rut depth, roughness, surface distress, surface deflection, and coring. Rutting will be assessed by measuring transverse profiles of the road surface mechanically (using the ARAN equipment), and manually (rod and level survey, and dipstick) during the spring and fall of every year. The methods will be evaluated in terms of cost, consistency, accuracy, and speed. Transverse profiles will be measured by taking levels at 150 mm intervals using rod and level, and 300 mm intervals using dipstick. A computer program is written in Quick Basic to plot the transverse profiles obtained manually and subsequently to calculate the rut depths for both wheel paths. First, this program determines the highest points for each transverse profile, on either side of the wheel track. Secondly, it estimates the distance between the line joining these maximum points and the lowest point on each wheel path to give the rut depth in millimetres. Finally, it calculates the average rut depth based on 10 cross profiles taken at 30 m intervals for each section.

Road roughness will be measured twice a year, in the spring and fall, both mechanically (ARAN) and manually (rod and level). Manual measurements of longitudinal road profiles include leveling at 500 mm intervals which will be used to characterize road roughness using a standard roughness statistic such as Mean Absolute Vertical Acceleration, (MAVA). Surface defects, including cracking, will be evaluated according to specified procedures [10], and also by crack mapping. Finally, the structural strength of the pavement test sections will be determined using (FWD). These tests should be conducted at 30 m intervals on the right wheel path. Three separate load levels will be used at each test point with the observed data (deflections) normalized for a standard wheel load of 40 kN and temperature of 21°C. These deflections, together with known layer thicknesses, will be used to back - calculate the elastic stiffness of all pavement layers. The deterioration of the structural strength of pavement layers will be assessed by observing the changes in elastic layer stiffness values.

Samples will be cored from test sections according to the plan shown in Figure 15. These samples will be analyzed in the laboratory to examine variability in the Marshall properties of the in situ pavement test sections over time, and to study the effect of such variation on pavement surface distress.

The purpose of the laboratory tests (Figure 16) is to compare the potential of modified mixes to resist rutting and low temperature cracking with that of the standard HL 1 mix. The results of some of the quality control tests carried out using plate samples and cored samples during construction are already included in Appendix 1. The remaining tests will be carried out in due course.

8/ Conclusions and Recommendations

1) The trial sections with Vestoplast, Novophalt (Polyethylene), Neoprene, tire rubber, and Premium Asphalt could be constructed successfully using conventional equipment. However, special blending equipment is required on site to mix polyethylene and tire rubber with asphalt cement.

2) The mix with Neoprene additive indicated a tendency to pick up during compaction with an 18 t rubber tired roller. This problem was resolved by allowing the surface of the mat to cool.

3) The field trial tests using the plate and cored samples indicate that the mixes used for the trial sections meet the mix design specification with the exception of samples from the binder course representing Novophalt, tire rubber, and Neoprene which gave slightly lower asphalt content. This could be attributed to the metering problems due to plugging encountered during mixing.

The following recommendations are made for consideration of future work.

1) During mixing, care should be taken to ensure that there is no plugging in the strainer particularly when the operation is changed from one additive to another.

2) The test sections should be monitored for at least five years. During this period, field performance evaluation should be carried out twice a year (spring, and fall) with regard to rutting and roughness, and once a year for condition survey (summer) and deflection measurements (spring).

Acknowledgements

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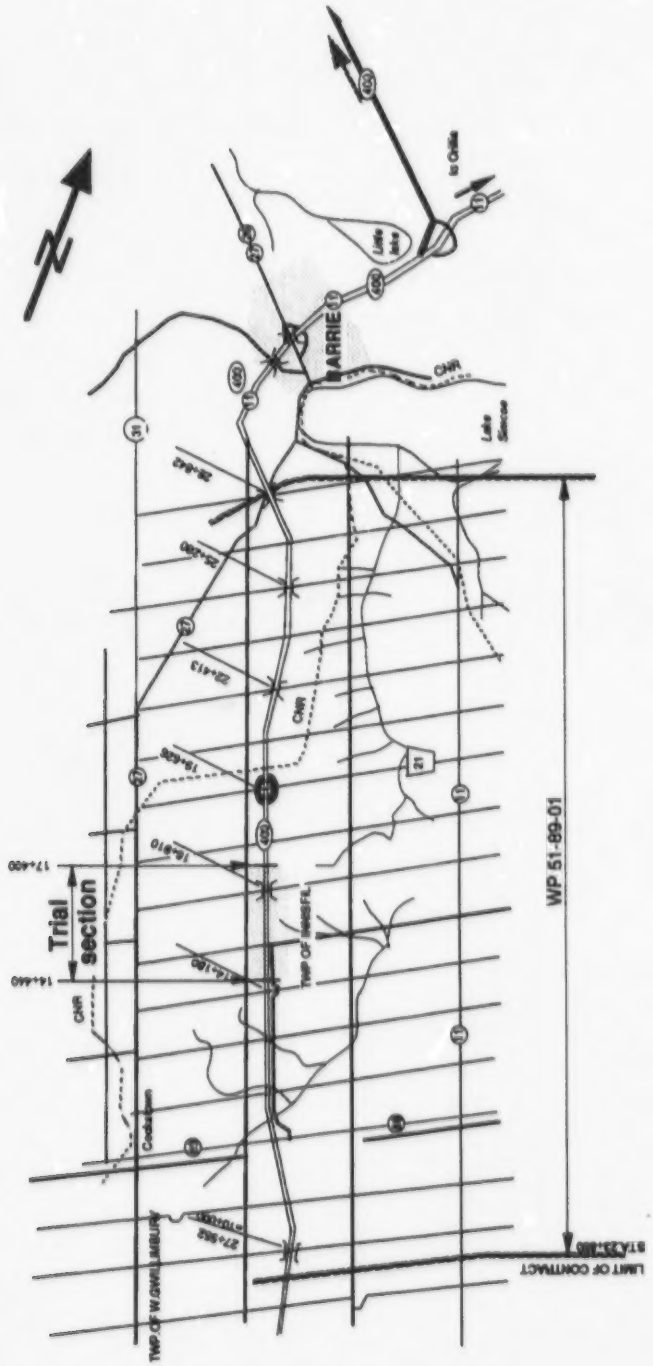

Figure 1/Project location map

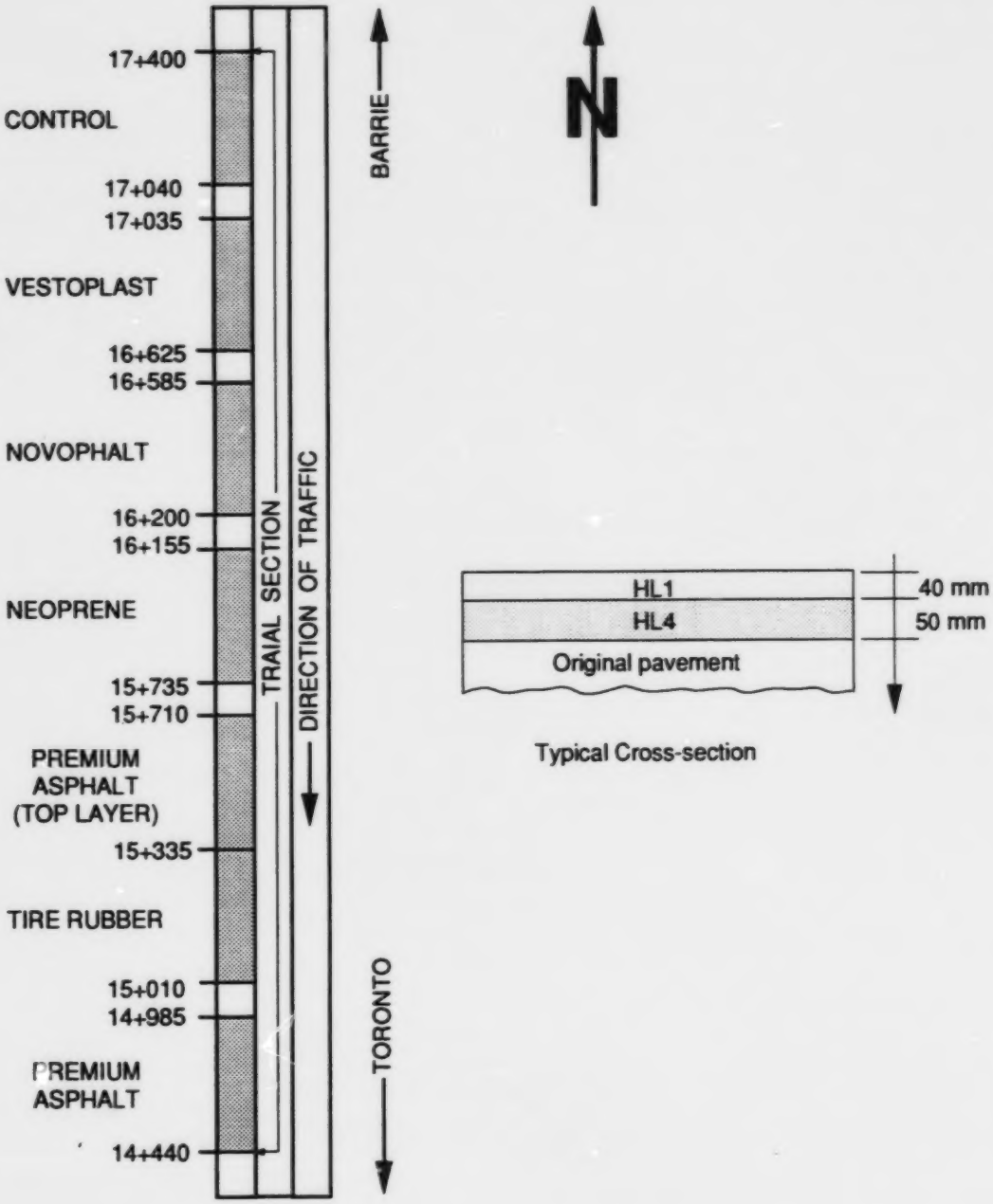

Figure 2/ Layout of trial sections

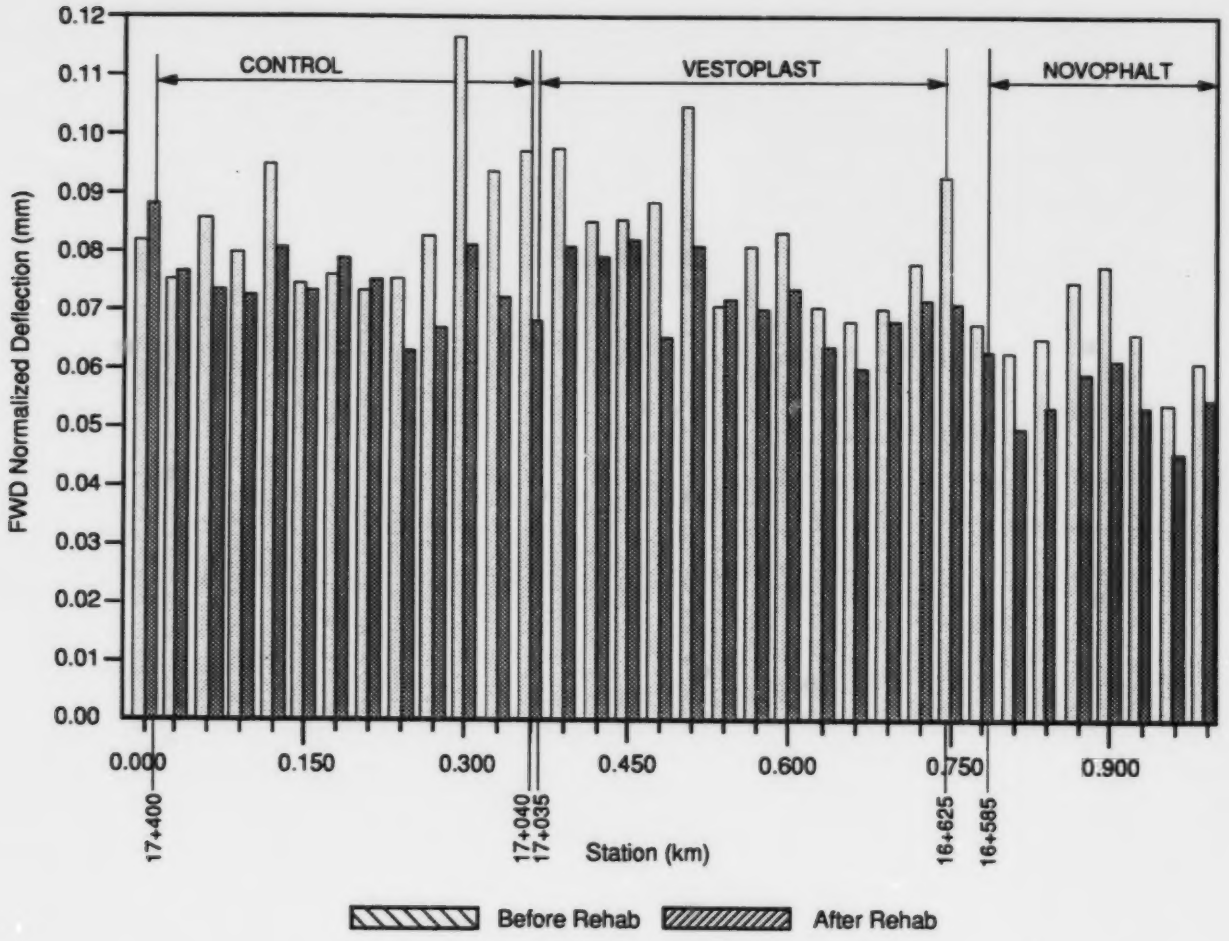

Figure 3/ Pavement falling weight deflectometer test results
(from station 0 to 1)

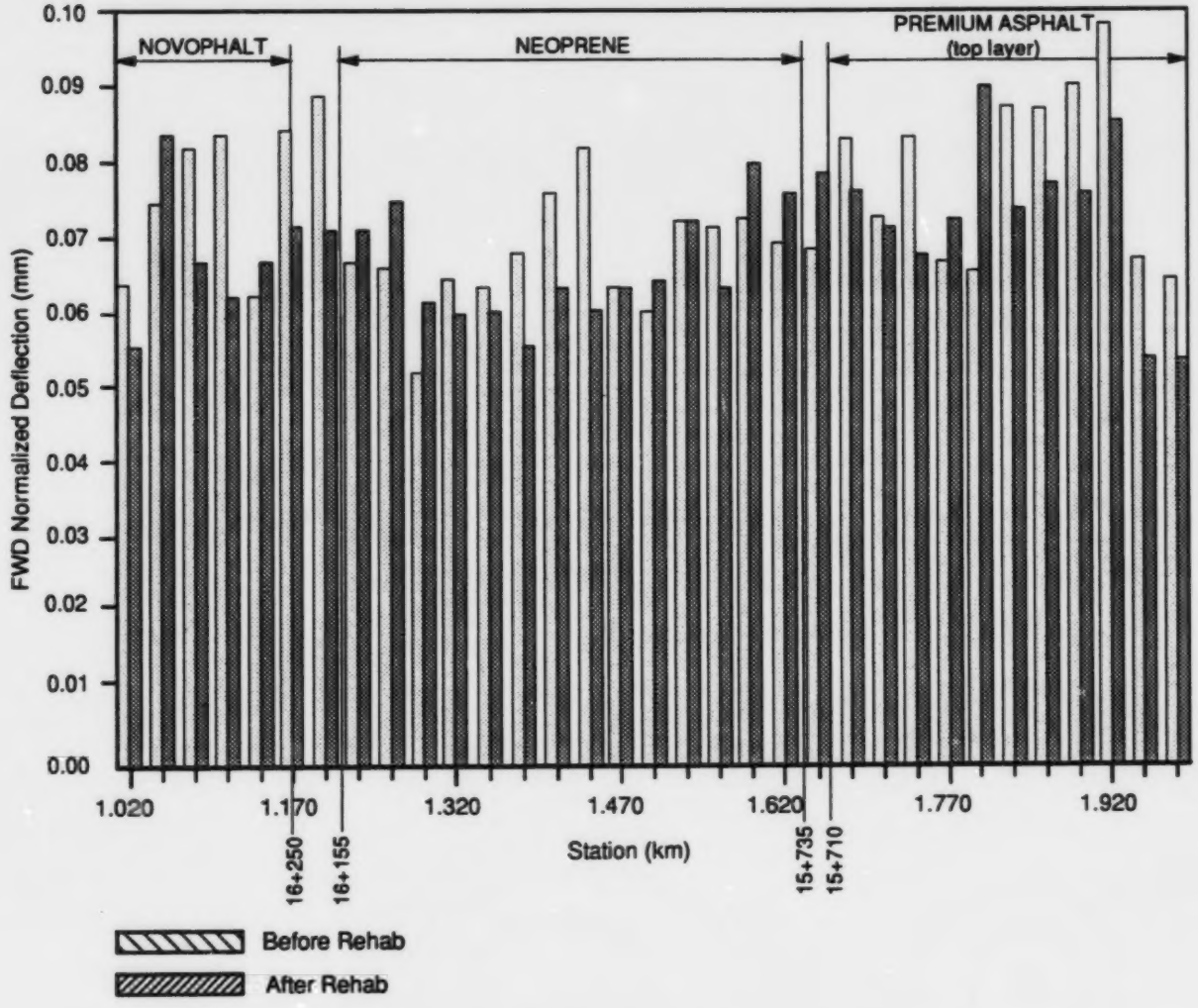

Figure 4/ Pavement falling weight deflectometer test results
(from station 1 to 2)

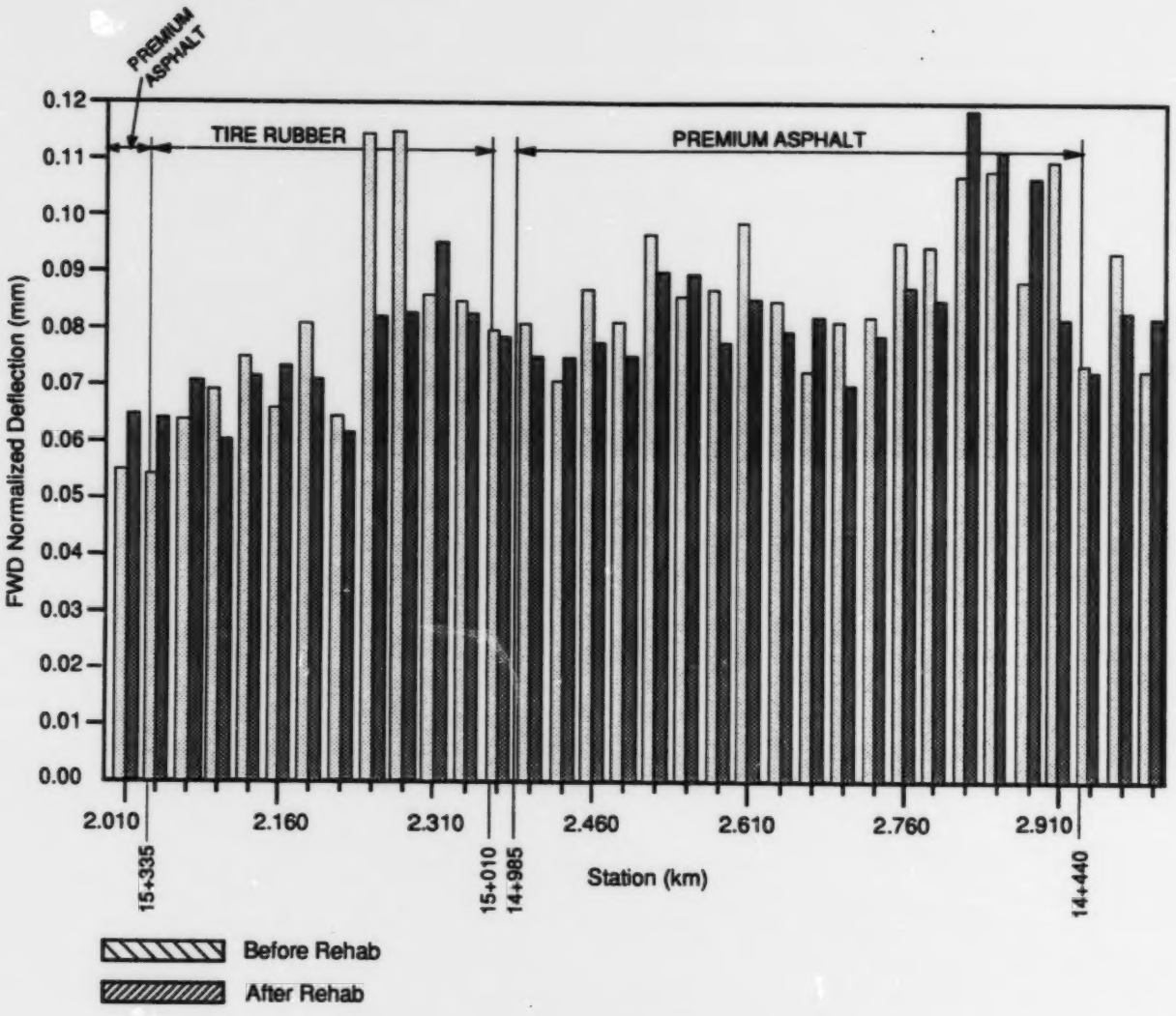

Figure 5/ Pavement falling weight deflectometer test results
(from station 2 to 3)

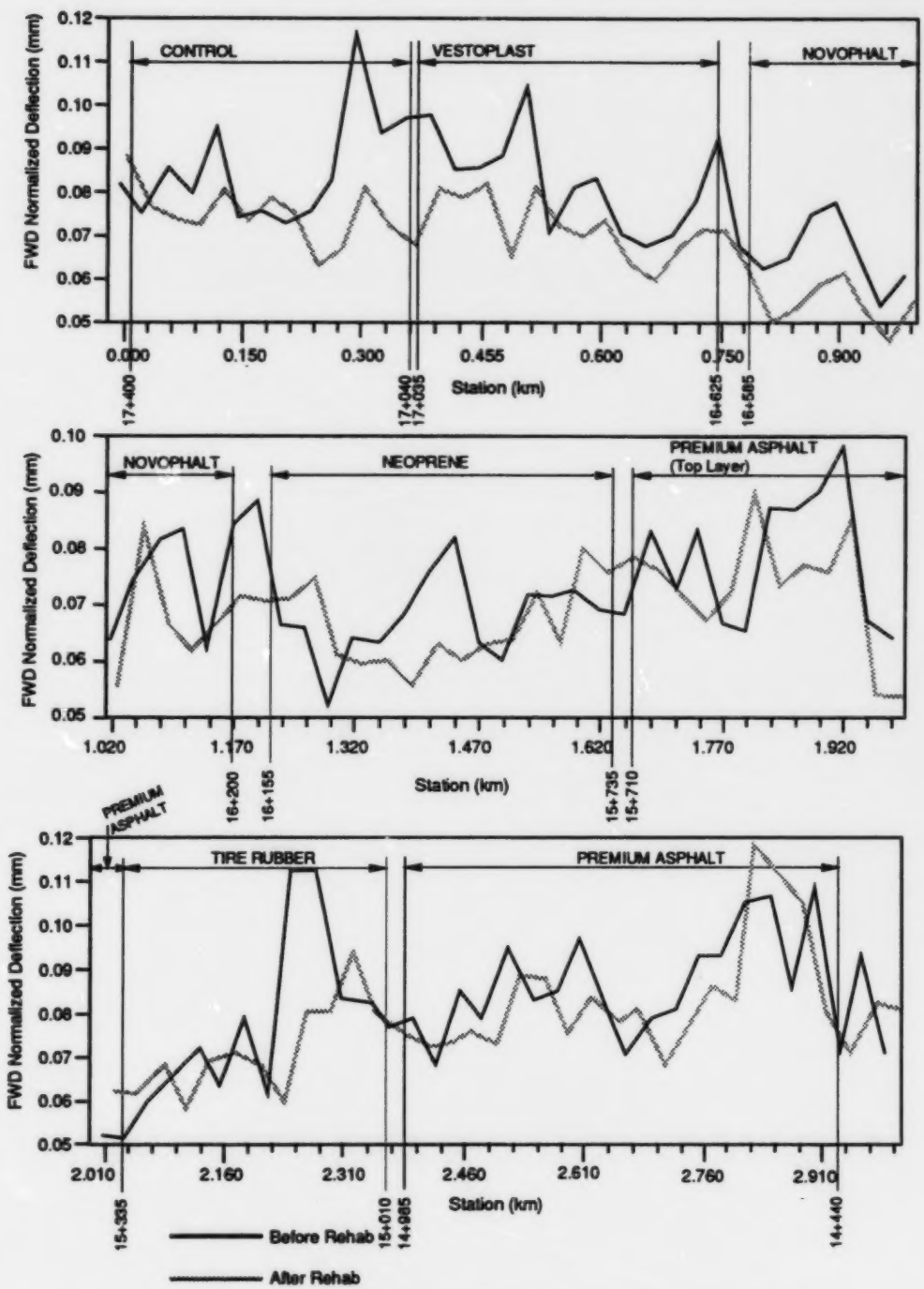

Figure 6/ Pavement falling weight deflectometer test results
(from station 1 to 3)

Figure 7/ Vestoplast bags stacked up near the front mix plant

Figure 8/ Conveyer belt carrying Vestoplast into the hot mix plant

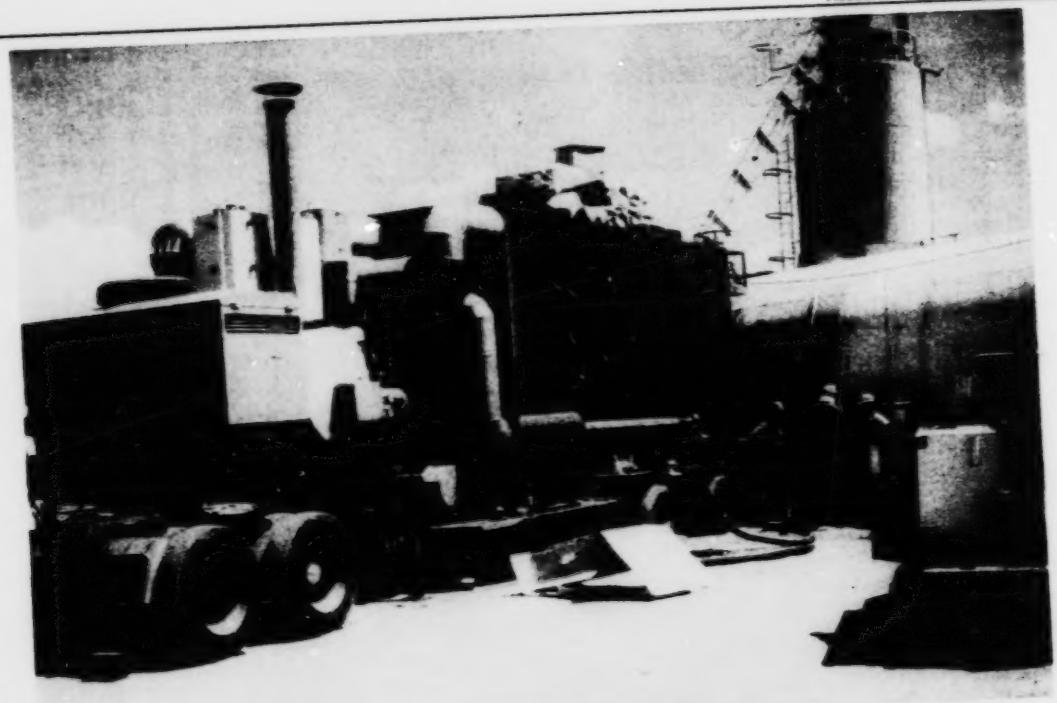

Figure 9/ A view of Novophalt blending equipment

Figure 10/ Adding Polyethylene into the blending equipment

Figure 11/ Hot mix samples taken at the exit of the mixer

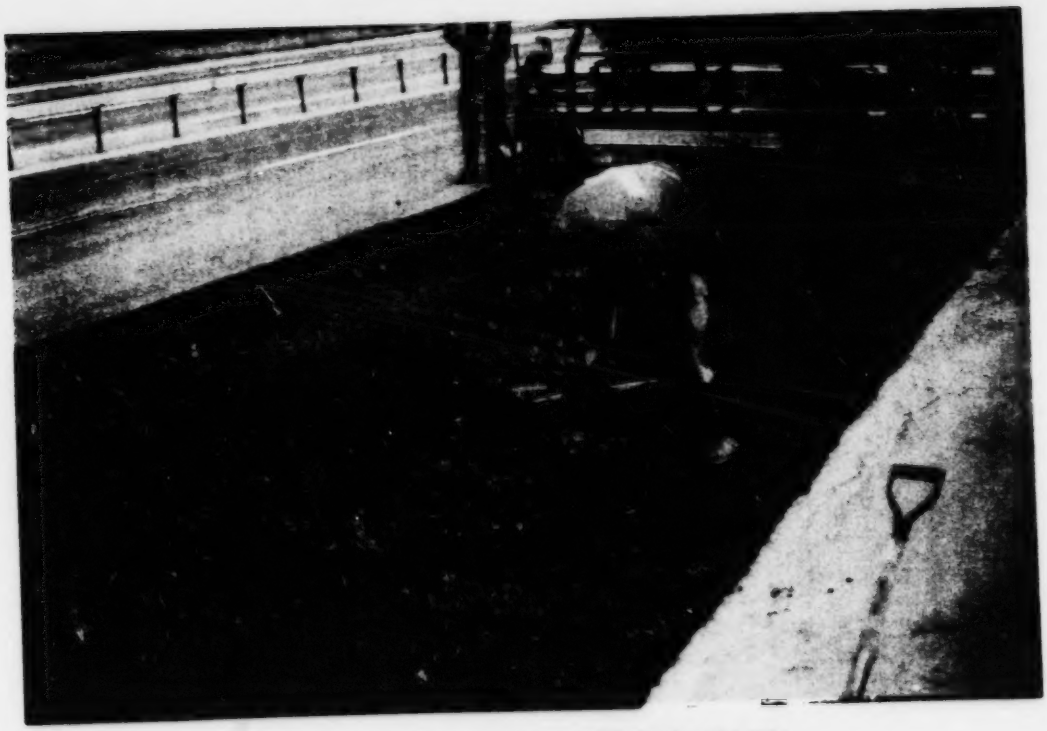

Figure 12/ Plate sample taken while laying the mix

Figure 13/ Plate sample ready for testing

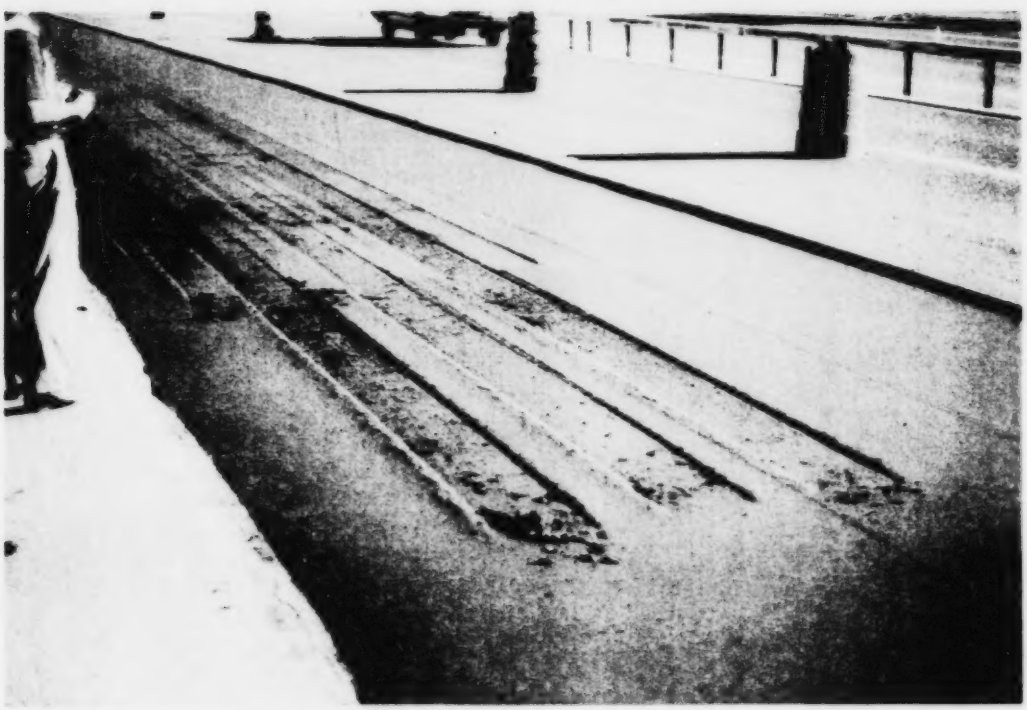

Figure 14/ Pick-up during compaction of Neoprene mix with pneumatic tires

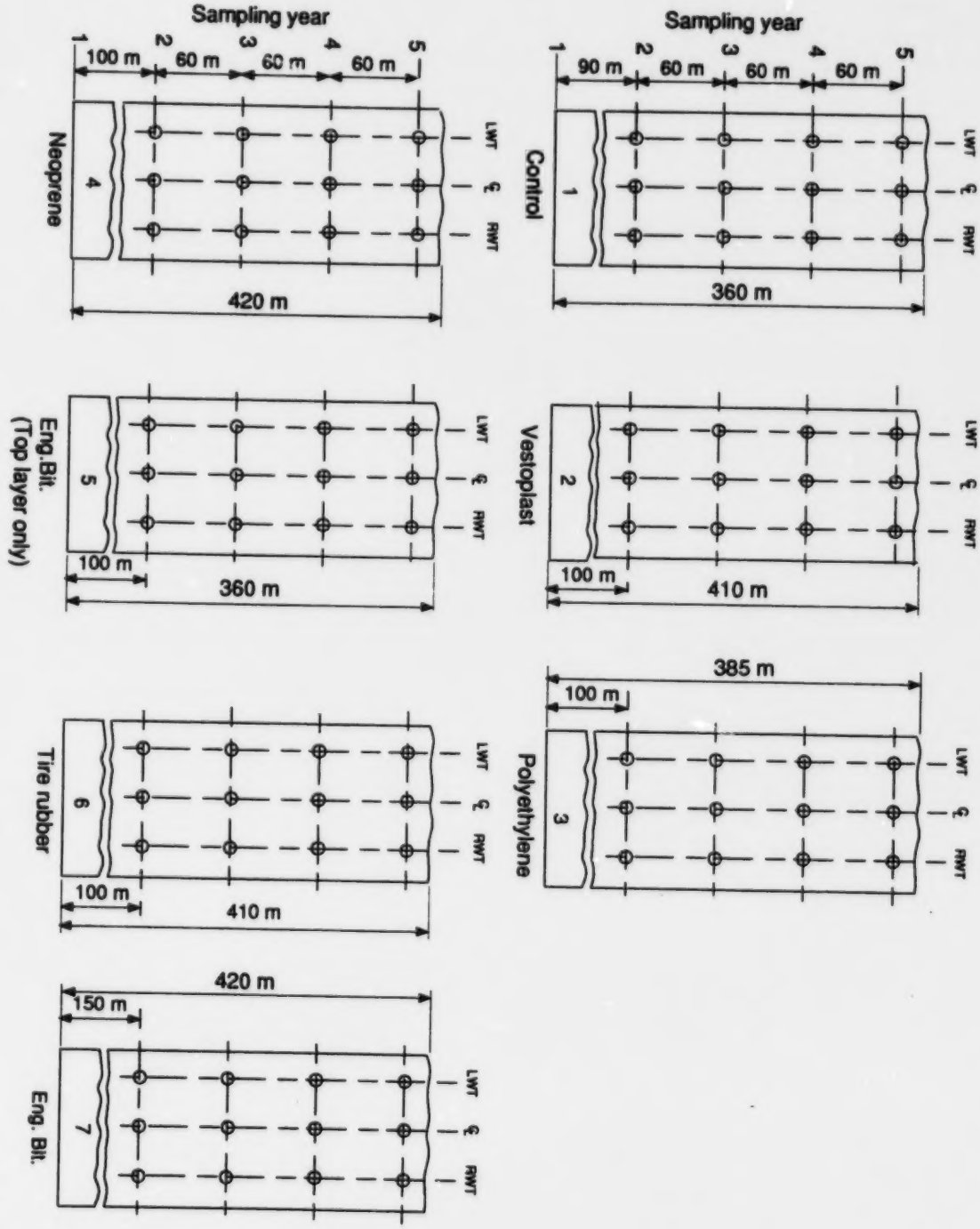

Figure 15/ Field sampling schedule for test sections

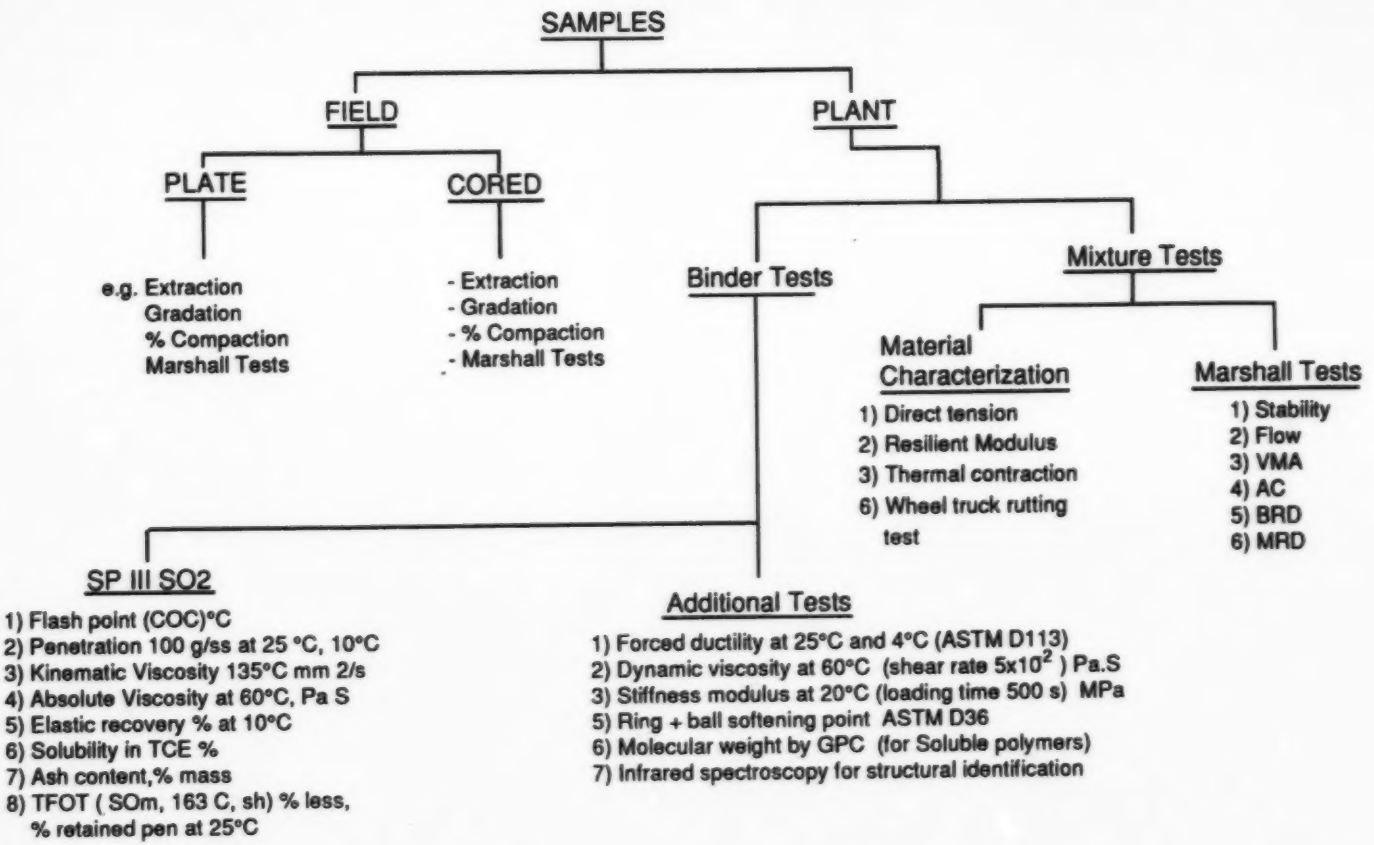

Figure 16/ Proposed laboratory tests

Table 1/ Asphalt cement blend characteristics

Product Type	*85-100 Pen*
Supplier	*Petro Canada*
Viscosity at 135 °C CST	*361.1*
Flash °C COC	*260+*
Pen at 25°C, 100g, 5 sec.	*89*
Duct. at 25°C CM	*25.5*
Recovered Pen	*56*

Table 2/ Aggregate gradation for HL 1 and HL 4 mixes

SIZE			mm						μ mm			
			16	13.2	9.5	4.75	2.36	1.18	600	300	150	75
HL1 Surface course	% passing	CA #1	100	99.5	60.5	3.8	0.3	0.2	0.2	0.2	0.2	0.1
		FA #1		100	99.6	95.1	88.2	79.4	62.5	27.4	4.9	1.1
		FA #2			100.0	81.2	54.0	33.5	21.3	13.8	9.8	7.5
		Final	100	99.8	80.1	47.7	4.0	34.1	26.2	12.1	3.2	1.4
HL4 Binder course	% passing	CA #1	100.0	85.8	49.0	4.0	1.7	1.5	1.4	1.3	1.3	1.1
		FA #1		100.0	99.6	95.1	88.2	79.4	62.5	27.4	4.9	1.1
		Final	100	93.8	77.3	55	50.1	45.1	35.6	15.9	3.3	1.1

Aggregate Type	Blending ratio, %	Mix Type	Description	Source	Inventory Number
CA # 1	50	HL 1	HL 1 Stone	3M Canada Havelock	C01-054-00
FA # 1	37.5		Asphalt Sand	Sass Pit, Allan G. Cook	B03-052
FA # 2	12.5		Screenings	Coldwater, Lavering Quarry, Allan G. Cook	B-03052-00
CA # 1	44	HL 4	HL 4 Stone	Coldwater, Lavering Quarry, Allan G. Cook	P22-35-0
FA # 1	56		Asphalt Sand	Sass Pit, Allan G. Cook	P22-35-0

Table 3/ Mix design test data – HL surface course

Marshall Properties	*MIX #*					*Spec.*
	1	2	3 *(selected)*	4	5	
Specific Gravity - Bulk - Maximum	2.485 2.648	2.499 2.626	2.514 2.604	2.522 2.583	2.524 2.562	
Air Voids, % vol	6.2	4.8	3.5	2.4	1.5	3-5
VMA, % vol	15.2	15.1	15.1	15.2	15.6	14.5
Marshall stability, N	8130	8645	9340	9105	8510	8900 min.
Marshall flow, 25 mm	7.4	7.8	8.8	105	13.0	8.0
Asphalt content, % wt	4.0	4.5	5.0	5.5	6.0	

Table 4/ Mix design test data HL 4 binder course (special design)

Marshall Properties	*MIX #*						*Spec.*
	1	2	3	4	5	6 *(selected)*	
Specific Gravity - Bulk - Maximum	2.343 2.497	2.359 2.478	2.374 2.460	2.368 2.440	2.386 2.422		2.383 2.444
Air Voids, % vol	6.2	4.8	3.5	2.2	1.5	3.5-5.5	2.5
VMA, % vol	16.4	16.3	16.2	16.2	16.6	15.0	16.2
Marshall stability, N	5995	6865	7345	7615	7385	8000	7560
Marshall flow, 25 mm	6.5	7.0	7.6	9.4	11.3	8.0	9.0
Asphalt content, % wt	4.5	5.0	5.5	6.0	6.5		5.9

Appendix 1

In Situ Quality Control Test Results

Table A1/ Field Marshall test results for surface course (HL 1)

Mix	AC%	Passing, % 4.75, mm	Passing, % 75, μ mm	BRD	MRD	Voids %	Flow 0.25 mm	Stability N	VMA %
Control Strip	5.28	48.3	2.9	2.520	2.599	3.0	10.2	12215	15.1
Vestoplast	5.56	50.8	3.1	2.529	2.574	1.7	12.9	13962	15.1
Novophalt	4.74	47.9	2.6	2.510	2.612	3.9	11.0	12792	15.0
Neoprene	4.72	46.2	2.7	2.519	2.623	4.0	11.9	13307	14.7
Tire Rubber	4.82	47.3	2.9	2.524	2.618	3.6	12.6	12985	14.6
Premium Asphalt	4.90	49.8	3.0	2.502	2.611	4.2	11.6	13919	15.4
Design Value	5.00	47.1	1.4	2.514	2.604	3.5	8.8	9340	15.1

Table A2/ Field Marshall test results for binder course (HL 4)

Mix	AC %	Passing, % 4.75, mm	Passing, % 75, μ mm	BRD	MRD	Voids %	Flow 0.25 mm	Stability N	VMA %
Control Strip	6.19	58.1	2.5	2.344	2.449	4.3	10.1	6678	17.8
Vestoplast	6.82	61.5	2.6	2.365	2.424	2.4	11.0	9359	21.6
Novophalt	5.37	60.6	1.9	2.336	2.470	5.4	8.9	11632	17.4
Neoprene	5.16	54.8	2.2	2.358	2.485	5.1	10.7	7246	16.4
Tire Rubber	5.14	58.5	2.0	2.319	2.476	6.3	10.3	7776	17.8
Premium Asphalt	6.17	60.3	2.5	2.336	2.448	4.6	9.1	10769	19.8
Design Value	5.90	55.0	1.1	2.383	2.444	2.5	9.0	7560	16.2

BRD – Bulk Relative Density
MRD – Maximum Relative Density
VMA – Voids in Mineral Aggregate

Table A3/ Thickness and BRD of surface course

Mix	Station and Offset from Centre Line	Thickness of Core, mm	BRD of core	BRD of Recompacted Samples	% Compaction
Control Strip	17 + 200 SBDL O/S 1.1 RT E/P	35	2.438	2.520	96.7
	17 + 109 SBDL O/S 3.0 RT E/P	33	2.436	2.518	96.7
Vestoplast	16 + 950 SBDL O/S .9 RT E/P	34	2.428	2.532	95.9
	16 + 835 SBDL O/S 1.7 RT E/P	37	2.468	2.534	97.4
Novophalt	16 + 397 SBDL O/S 2.4 RT E/P	42	2.388	2.494	95.7
	16 + 261 SBDL O/S 3.1 RT E/P	43	2.347	2.457	95.5
Dupont	16 + 111 SBDL O/S 0.7 RT E/P	40	2.430	2.491	97.6
	16 + 028 SBDL O/S 1.3 RT E/P	42	2.405	2.499	96.2
Petro-Canada	15 + 680 SBDL O/S 1.3 RT E/P	33	2.444	2.526	96.8
	15 + 425 SBDL O/S 1.0 RT E/P	39	2.399	2.508	95.7
Tire Rubber	15 + 191 SBDL O/S 1.9 RT E/P	34	2.431	2.513	96.7
	15 + 088 SBDL O/S 2.7 RT E/P	48	2.438	2.528	96.4
Premium (both layers)	14 + 818 SBDL O/S 1.9 RT E/P	43	2.394	2.527	94.7
	14 + 529 SBDL O/S 0.6 RT E/P	53	2.477	2.518	98.4

BRD - Bulk Relative Density

Table A4/ Thickness and BRD of binder course

Mix	Station and Offset from Centre Line	Thickness of Core, mm	BRD of core	BRD of Recompacted Samples	% Compaction
Control Strip	17 + 200 SBDL O/S 1.1 RT E/P	68	2.369	2.370	100.00
	17 + 109 SBDL O/S 3.0 RT E/P	64	2.337	2.364	98.9
Vestoplast	16 + 950 SBDL O/S .9 RT E/P	68	2.376	2.382	99.7
	16 + 835 SBDL O/S 1.7 RT E/P	40	2.362	2.372	99.6
Novophalt	16 + 397 SBDL O/S 2.4 RT E/P	49	2.303	2.348	98.1
	16 + 261 SBDL O/S 3.1 RT E/P	65	2.292	2.329	98.4
Dupont	16 + 111 SBDL O/S 0.7 RT E/P	57	2.317	2.378	97.4
	16 + 028 SBDL O/S 1.3 RT E/P	55	2.337	2.371	98.6
Petro-Canada	15 + 680 SBDL O/S 1.3 RT E/P	55	2.367	2.374	99.7
	15 + 425 SBDL O/S 1.0 RT E/P	65	2.360	2.365	99.8
Tire Rubber	15 + 191 SBDL O/S 1.9 RT E/P	55	2.316	2.316	98.9
	15 + 088 SBDL O/S 2.7 RT E/P	60	2.325	2.325	99.3
Premium (both layers)	14 + 818 SBDL O/S 1.9 RT E/P	55	2.340	2.370	98.7
	14 + 529 SBDL O/S 0.6 RT E/P	40	2.351	2.373	99.1

BRD - Bulk Relative Density